United States
Department of
Agriculture

Forest Service

Pacific
Northwest
Region

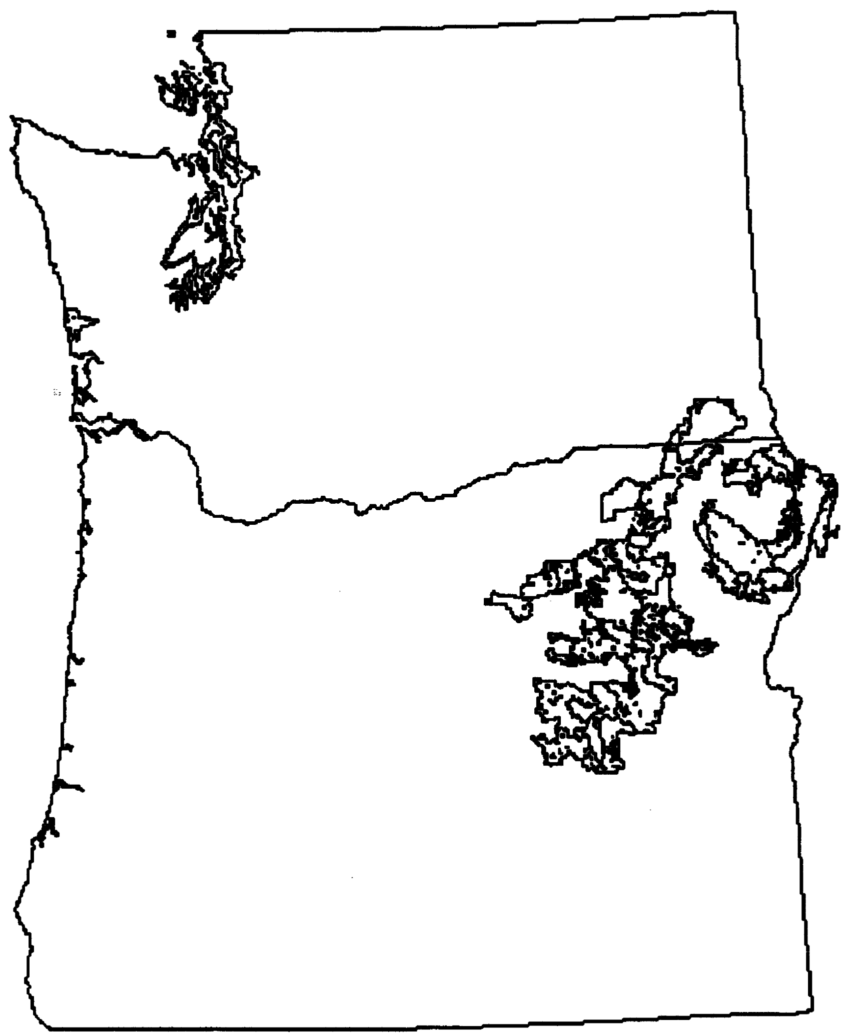
**Blue Mountains Pest
Management Zone**

**Wallowa-Whitman
National Forest**

BMZ-94-10
June 30, 1994

WESTERN SPRUCE BUDWORM AND DOUGLAS-FIR TUSSOCK MOTH POPULATIONS ON ANALYSIS UNITS IN THE BLUE MOUNTAINS IN 1993

By: Donald W. Scott



Caring for the Land and Serving People

Western Spruce Budworm and Douglas-fir Tussock Moth Populations on Analysis Units in the Blue Mountains in 1993

Donald W. Scott, Zone Entomologist

Blue Mountains Pest Management Zone
Wallowa-Whitman National Forest
La Grande, Oregon 97850

Report No. BMZ-94-10
June 30, 1994

WESTERN SPRUCE BUDWORM AND DOUGLAS-FIR TUSSOCK MOTH POPULATIONS ON ANALYSIS UNITS IN THE BLUE MOUNTAINS IN 1993

Donald W. Scott, Zone Entomologist

Blue Mountains Pest Management Zone
Wallowa-Whitman National Forest
La Grande, Oregon 97850

June 30, 1994

Introduction

Western spruce budworm (*Choristoneura occidentalis*) populations have fluctuated in the Blue Mountains of northeastern Oregon and southeastern Washington since the outbreak began near Cove, Oregon, in 1980. Budworm, and the Douglas-fir tussock moth (*Orgyia pseudotsugata*) which historically increases to outbreak at roughly 7 to 10 year intervals (Clendenen 1975; Shepherd et al. 1988), are the two most destructive defoliators of Douglas-firs and true firs in mixed conifer stands in the Blue Mountains.

Populations of these two defoliators fluctuate independently of one another, but may obtain outbreak levels simultaneously, in the same locales. This has occurred in some areas of the Blue Mountains during the last 3 or 4 years.

Ranger Districts on the Malheur, Umatilla, and Wallowa-Whitman National Forests, other federal agencies, and states of Oregon and Washington have closely followed the fluctuations of budworm and tussock moth populations through periods of increase and decline for a number of years. Various administrative units have annually identified analysis units to determine need for managing defoliator outbreaks where unacceptable resource damage appeared imminent. In a cooperative effort, areas with high budworm populations on federally-managed lands, and adjacent lands under state and private management, were identified and analyzed during 1993. Likewise, tussock moth analysis units were established during the last 3 or 4 years because of increasing insect populations and potential for unacceptable resource damage.

In the fall of 1992, a few new analysis units were proposed for analysis. These were in addition to proposed re-analysis of units sampled the previous year that continued to have high populations and unacceptable damage of concern to resource managers. In addition,

some districts were interested in re-examining areas that had been treated in recent years with the microbial insecticide, *Bacillus thuringiensis* Berliner (*B.t.*), to suppress outbreaks of tussock moth and budworm. The purpose of resampling previously-treated areas was to monitor post-treatment populations to verify that populations remained low in accordance with Forests' Monitoring of Land and Resource Management Plans for Insect and Disease Management.

A number of other budworm analysis units were established and sampled in earlier years, but those will not be reported on here. Hence, this is a representation of only those analysis units sampled during 1993. This report summarizes the results of lower crown sampling for defoliators during the 1993 season. The analysis units identified in table 1 are those that were sampled for budworm and/or tussock moth during 1993 by lower crown beating (LCB). In addition, pheromone trapping results from private lands adjacent to analysis units on the Walla Walla RD, and trapping results from the Skyline analysis unit on the Pomeroy RD, are reported here. No other areas were monitored by budworm pheromone trapping as part of thi assessment during 1993. Annual tussock moth pheromone trapping was conducted in 1993 on districts, but those data will not be reported here. That effort is part of the Regionwide Douglas-fir tussock moth Early Warning System, and results were summarized by the Pacific Northwest Region, for the entire Region, and have been reported by Willhite (1994).

<u>Larval Sampling</u>

Lower crown sampling procedures for budworm described by Mason et al. (1989) were used to sample host trees (primarily Douglas-fir, grand fir, and white fir) in mixed conifer stands on analysis units in 1993.

A similar method was used to sample tussock moth populations. The procedure for sampling tussock moth by complete counts of larvae in branch samples is described by Mason and Paul (1994). Instead of predicting midcrown densities of tussock moth larvae from the proportion of sample units infested in the lower crown (cf. Mason 1977b), we made direct counts of larvae in the lower crown after beating branches in the lower crown to dislodge larvae onto a hand-held beating frame and cloth.

Additional budworm and tussock moth sampling information and guidelines that were used were provided by Scott (1991b, 1991c). In general, sampling unit sizes conformed to Regional standards (Sheehan et al. 1993). A minimum of 30 plots were sampled in each analysis unit. If analysis unit size exceeded 30,000 acres, then the plot density was at least 1 plot per 1,000 acres of analysis unit size (see Table 2). In practice, however, plot size varied considerably from one analysis unit to another or from one district to another (Table 2); thus, some variance from Regional standards occurred. This was due to the fact that some analysis units were sampled for pre-suppression purposes while other areas were either sampled for post-suppression purposes or for other population monitoring reasons.

The number of host trees sampled on each plot was nearly uniform over all analysis units sampled in the Blue Mountains in 1993. With the exception of the Heppner Ranger District which sampled 10 trees per plot, all analysis units were sampled at an intensity of 5 trees per plot. The primary sampling unit was three 18-inch lower crown branches per tree (Mason 1977b; Mason et al. 1989).

Data analysis utilized the MUST computer program for multiple-stage sampling data (Hazard and Stewart 1974) to compute larval sampling statistics. A two-stage design was employed with plots as the first sampling stage, and trees within plots as the second sampling stage.

Other details of the larval sampling were previously described by Scott (1991a).

Adult Trapping

Adult moths were trapped at several locations in the fall of 1993 and the data were used to predict defoliation levels on those locations in 1994 (C. Sartwell, unpublished data). The methods used in conducting adult trapping were previously described by Scott (1991a).

Results and Discussion

Western Spruce Budworm

Budworm densities were extremely low in 1993. For most analysis units, the midcrown densities (larvae per 18-inch branch tip), converted from densities determined by lower crown sampling of budworm populations, were one or less larvae per branch tip (Table 3). Highest densities were found on private lands sampled by Oregon Department of Forestry personnel (Pendleton office) adjacent to the Walla Walla/Mill analysis unit. These lands averaged slightly over four larvae per 18-inch midcrown branch tip.

All areas treated with *Bt* during 1991 or 1992 (i.e., Catherine Creek, Indian Creek, Mt. Emily, Morgan, and Kuhn-Chesnimnus) contained extremely low populations of budworms (Table 3). Budworm populations on some of these analysis units were so low they could not be detected by lower crown sampling in 1993.

Pheromone trapping of the limited areas that were trapped yielded results similar to lower crown sampling. Trap catches of adult budworm males were extremely low. They ranged from an average of 0.5 moths per trap on the private lands of the Thimbleberry analysis unit to 1.07 moths per trap on the Skyline analysis unit of the Pomeroy RD. All trap catches predict light defoliation levels for 1994, based on the scheme described by Scott (1991a). Given the population trend, it is likely that the defoliation in 1994 may be nearly imperceptible over most of the Blue Mountains. Budworm-caused defoliation in the Blue

Mountains during 1993 was so light that none was mapped during the aerial insect detection survey (Scott and Schmitt 1994). Defoliation of current-year tips in 1993 ranged from 0 to 71 percent, but most locations had considerably less than 50 percent of the current-year foliage missing (Table 3).

Declining budworm populations in the Blue Mountains appear to follow a region-wide trend for 1993. Budworm populations in most places declined dramatically from previous years throughout the region.

We have no specific data on the factors primarily responsible for the decline of the populations. However, we know from our population sampling the last couple of years that the rapid general decrease in budworm numbers really began in 1992. From lower crown budworm sampling of nominal fourth-instar (L_4), and later pheromone trapping of adults, we discerned a dramatic decline in numbers between these two sampling periods in 1992. During the 1992 sampling season a number of ranger district personnel reported "disappearance" of older larvae and pupae in casual observations they made from areas where they observed relatively higher populations of larvae during previous visits. We also observed a similar phenomenon in many areas of the Blue Mountains at about that same time. It seemed that natural factors were at work reducing numbers of budworm over widespread infested areas. While observations of parasitized larvae were not uncommon, and various known budworm predators (e.g. spiders, ants, and various birds) were observed in association with budworm populations, no single factor, including weather, could be pinpointed as most responsible for this obvious decline.

Our observations were similar to region-wide collapses of populations of the western spruce budworm's eastern relative, the spruce budworm, *C. fumiferana*, most notably in Newfoundland (Raske 1985), and in New Brunswick, Canada (Royama 1984). The western spruce budworm populations in the Blue Mountains "disappeared" mostly between the L_4 and L_6 stages, in a manner characteristic of the population collapses studied in these two reports from Canada. Royama (1984) described the intrinsic (density-dependent) mortality factors as including ". . . parasitoids and, probably, diseases (e.g. microsporidian infection), and most important, an intriguing complex of unknown causes, which I term 'the fifth agent' (a large number of larvae with no clear symptoms died during the population decline in the late 1950s)." Royama did not believe that in the New Brunswick outbreak, the other mortality factors, including predation, food shortage, weather, and losses during the spring and fall dispersal of young larvae were significant factors in the basic, universal collapse of local populations.

Regardless of the causes, it is clear that the present decline of budworm populations began during 1992, continued into 1993, is widespread throughout the Blue Mountains and the Pacific Northwest Region, and has effectively reduced populations to negligible numbers for 1993. We expect these numbers to remain low during the 1994 season, as well.

If history is any indication, the cessation of this outbreak may signal ensuing endemic population fluctuations that typify lower to mid ranges of the historic range of variability of budworm in the Blue Mountains for quite a number of years, and perhaps several decades. Evidence to support this statement comes from recent tree ring analysis from the northern Blue Mountains (Swetnam and Wickman, unpublished data at Tree Ring Laboratory, University of Arizona, personal communication). The analysis of old-growth stands in the northern Blue Mountains suggest that budworm outbreaks occurred with a frequency interval of approximately 40 to 50 years before 1900, and at roughly 20 to 30 year intervals since about 1900. Natural enemies, intrinsic factors and environmental processes, especially weather, operate to regulate budworm population levels during the periods between outbreaks. Periods of protracted drought seem to be correlated with some past outbreaks of budworm (Gast et al. 1991), although we don't know the precise causes of outbreaks.

Although foliage recovery may soon mask much of the damage to trees caused by year's of severe budworm defoliation, many trees over thousands of acres have been killed by budworm, drought, bark beetles, and diseases, acting independently or in concert; and, many others have had considerable radial growth loss, and will manifest bole deformities from top-killing by budworm in future decades.

Refoliation of severely defoliated trees began last summer (1993). However, there is a danger in being lulled into thinking all trees showing recovery of foliage will survive, or that the budworm damage has not been as serious as first thought. While many damaged trees will survive, many other trees have been weakened to the point that they will either die from subsequent year's of moisture stress if drought continues, or will succumb to bark beetle attacks, having been predisposed through depletion of stored carbohydrates reserves (Christiansen et al. 1987).

Significant research over the years has shown that both defoliation and severe drought stress reduces the starch reserves in trees (Scott and Schmitt 1994). This important carbohydrate reserve is needed for numerous physiological and biosynthetic processes that help trees grow and survive agents that weaken trees . If starch levels are reduced beyond a certain point, the weakened tree dies, or soon becomes a target for bark beetle attacks that kill the tree (Scott and Schmitt 1994). Douglas-fir beetle, *Dendroctonus pseudotsugae*, populations that built up in habitats created by severe defoliation by budworm and drought stress, are continuing to maintain abnormally high populations. These beetle populations will continue to cause significant mortality to the large, mature, Douglas-fir components in mixed conifer stands in several areas of the Blue Mountains for the next several years.

Stands may appear to improve in the next several years because trees will recover from defoliation damage, but the condition of many of these mixed conifer stands on the Forests will remain seriously overstocked, will still contain an inappropriate mix of species where

true fir and Douglas-fir have invaded dry pine sites, and will be "set-up" for another serious outbreak of defoliators in the future. The budworm scenario we have just experienced will play out again, perhaps 2 to 3 decades into the future, with similar or greater magnitude unless actions are taken to push these stands back to earlier stages of seral succession. To avoid outbreaks of similar magnitude and intensity of damage, stands need to be returned to a condition of stocking and species composition that is within their natural ranges of variability, and were historically maintained that way by high-frequency, low-intensity surface fires (Everett et al. 1994; Hessburg et al. 1994).

Douglas-fir Tussock Moth

Douglas-fir tussock moth has become an ally with budworm, bark beetles, and drought during the past 4 or 5 years in hampering our efforts to manage resources in several places in the Blue Mountains. The last major tussock moth outbreak to occur in this region was during the early to mid 1970s. This previous outbreak was considerably more widespread, and more destructive to host trees within stands, than the recent outbreaks that have occurred on areas of the Pine, La Grande, Bear Valley, and Burns Ranger Districts, and portions of the Hells Canyon National Recreation Area.

Stand conditions that promoted the earlier outbreak of tussock moth, however, have really not changed much in the ensuing two decades since that outbreak. Moreover, recent efforts have still only been aimed at treating the "symptom" rather than the "cause." Regardless, annual monitoring of populations (monitoring sampling); evaluating expanding, potentially destructive populations prior to suppression treatment (pre-suppression sampling); and follow-up monitoring of insect management activities (Forest Plan Monitoring for Insect and Disease Control) are all necessary and integral parts of monitoring, evaluating, and managing the insect component of forest ecosystems and ecosystem processes. To that end, I report here, the results of sampling tussock moth populations in the Blue Mountains by Ranger District or Forest personnel during 1993.

Sampling for tussock moth during 1993 yielded mixed results. While only those analysis units on the Prairie City and Burns Ranger Districts (Malheur NF) were sampled specifically to determine Douglas-fir tussock moth populations in 1993 (Table 2), lower crown sampling for budworm on all other analysis units in 1993 simultaneously yielded population information about tussock moth for those budworm analysis units on other districts. Tussock moths, however, were detected from only the 1993 samples on the Malheur NF (Burns, Prairie City, and Long Creek Ranger Districts).

With the exception of the Burns Ranger District, all analysis units from Ranger Districts on the Malheur NF yielded "low" or "very low" tussock moth populations (Table 4). Midcrown densities were converted from lower crown sampling results for the Gold,

Rattlesnake, and Thompson Analysis Units in this table. These analysis units had populations of 63.8, 135.9, and 49.0 larvae per 1,000 square inches of foliated branch tip, respectively. Tussock moth densities in this range classify as "outbreak" (Mason 1977a).

We made a follow-up visit to the Burns Ranger District on September 13-16, 1993, to evaluate the late-season status of tussock moth in the three analysis units. Tussock moth had mostly reached the adult stage by this time and some had either mated and deposited egg masses, or were soon to begin egg deposition. We also found cocoons and late-instar larvae present, though we found many of the larvae to be parasitized. These would not survive to pupation. We found many of the pupae also had been parasitized.

Tussock moth populations, though varying in density, had dramatically declined from the levels sampled earlier that spring, based on casual observations. Defoliation of trees also varied between, and within, the analysis units. Defoliation ranged from light to heavy. The heaviest defoliation levels were noted for those areas where populations were probably highest from the beginning of the outbreak, though we could not confirm this. These heaviest areas of defoliation were mostly scattered in pockets of smaller acreage, and did not appear to extend over extremely large areas. However, these heavily-defoliated areas accounted for perhaps 37 percent of the total area defoliated. Trees of all sizes were virtually stripped of nearly all foliage in the areas of heaviest defoliation. Some smaller trees were dead from being defoliated and stressed by drought. Bark beetles undoubtedly will insure the mortality of some of the other surviving, severely weakened larger trees perhaps this year or next. Others, still, will manifest substantial top kill in subsequent years. Most of the areas appeared to have had moderate, or light--with some grading to very light--levels of defoliation, based on our observations. We did not make formal ocular estimates of tree defoliation during our September visit; however, the aerial insect detection survey mapped 9,851 acres of lightly-defoliated trees; 19,032 acres of moderately-defoliated trees; and 17,110 acres of heavy tussock moth defoliation on the Malheur NF in 1993.

Observations made in September, 1993, especially on the Rattlesnake Analysis Unit, indicated that the rate of mortality from various factors was higher than observations made the previous year. The proportion of insects surviving late in the season in 1993 was quite low relative to the high populations of 1992, and even from earlier sampling in the summer of 1993.

Population levels and conditions we observed in September, 1993, strongly indicated that the infestation had reached the peak of the outbreak, and multiple mortality factors were beginning to cause a rapid decline in the populations at all three locations. Nucleopolyhedrosis virus (NPV) was especially widespread in the populations. We observed classical symptoms of infection: dead larvae were frequently concentrated near the tops of trees and had died almost smeared on foliage, or hung limply upside down from foliage, attached only by abdominal and anal prolegs. Some pupae also contained virus-

laden haemolymph (insect blood) and were easily ruptured when probed.

Evidence of late larval and pupal predation and parasitization was also commonplace on all three analysis units. Parasitic wasps were found within moribund larvae, and parasitic flies (notably, *Carcelia yalensis*, which attacks late-instar larvae and emerges during the pupal stage) accounted for a considerable amount of the observed pupal mortality. Also, at various times we observed a species of stink bug (Pentatomidae), *Podisus sp.*, preying on pupae. It was not uncommon to find these true bugs preying on the tussock moth larvae that had not yet pupated by this time. The high levels of parasitization and predation by natural enemies that were observed were clearly having an impact on the populations.

Both larvae and egg masses were collected from all three areas, and returned to the laboratory for rearing to determine survival rates and causes of mortality. Egg masses were difficult to find and tended to be small, containing probably fewer eggs than those of vigorous populations. We collected only a limited number of larvae (30) for laboratory rearing. Of the 30 larvae collected and reared 3 (10%) died from parasitization; 13 (43%) died from NPV; and the remainder survived to adulthood. We anticipate that in field populations, additional numbers of tussock moth will die from disease, parasitization, and predation of the pupal and adult stages. Moreover, losses from starvation during the larval stages are common when populations reach such high densities as occurred on these analysis units.

We found only 5 egg masses to collect for rearing and virus determination during our visit in September 1993. The masses were placed in cold storage for 4 months to break diapause, prior to rearing. Of the 5 egg masses, 1 mass was essentially infertile, producing only 1 larvae which died before it could be reared to determine presence of virus. All remaining masses hatched normally. Larvae were collected from each mass and reared in individual petri dishes according to procedures described by Stelzer (1979). The individually-reared larvae from all four egg masses that hatched normally, died from NPV infection, indicating that the egg masses contained virus as we had suspected from our field observations. The fifth egg mass that failed to hatch normally probably also contained virus, but that could not be confirmed without actually rearing larvae from the mass.

The significance of this egg mass virus is: (1) that the presence of natural virus confirms and reinforces our field observations of high virus prevalence rates; and (2) that it portends an impending collapse of the tussock moth populations from which these egg masses came. In this regard, our observations are consistent with Stelzer (1979). He noted that, "In some areas, the effect of the natural virus is sufficient to initiate an epizootic or natural control of the tussock moth population."

We believe the preponderance of evidence of widespread mortality to tussock moth populations observed in the field, coupled with the results of rearing field-collected larvae and egg masses in the laboratory that we report above, unequivocally show that the

outbreak was in a state of collapse. We expect few survivors to carry numbers over into 1994. Many of those viable egg masses that overwintered last winter will likely become parasitized by tiny wasp species (most commonly, *Telenomus californicus*, and perhaps also by *Trichogramma minutum*) in late winter and early spring, before eggs begin to hatch. These parasitoids could have considerable impact this spring on the viability of remaining egg masses. We could not measure the impact of these egg parasitoids because our collections of egg masses occurred last fall, before these adult wasps became active.

Although we are confident that the tussock moth outbreak on the Burns Ranger District has collapsed, nevertheless, there may be isolated areas in 1994 where some populations may remain through the season, and even cause visible defoliation. Generally, we would expect these areas to be quite limited in size, and populations would probably not last beyond this season, based on our observations from the Wallowa-Whitman NF outbreak from a couple of years earlier. We are planning to make a final visit to these outbreak areas on the Burns Ranger District to confirm our predictions of the population collapse during July 1994.

Conclusions

Insect and disease perturbations will always be a part of the forested landscape of the Blue Mountains. Defoliator populations wax and wane, though most fluctuations are barely noticed. These small population increases and declines, and occassional outbreaks, probably follow historic patterns for defoliators. These defoliator oscillations are also part of the inherent changes occurring within the insect component that characterize their population dynamics and contribution to ecosystem process in mixed conifer stands in the Blue Mountains. When insect numbers are high over relatively limited areas for short periods of time, they contribute to the faunal diversity of the forest, to changes in the plant structural and compositional diversity, provide one food component for a number of other insect and warm-blooded animal species, and help to cycle nutrients, among other things. When insect populations increase to high levels and begin to interfere with the management of resources and levels of resource output desired by the public, we then consider these insects to be "pests" (Gast et al. 1991).

Unfortunately, some of our management practices--fire exclusion especially--over the past 70 or 80 years have contributed to the development of vast expanses of favored habitat for both budworms and tussock moths. Following European settlement around 1850, heavy livestock grazing diminished grasses and forbs--the fine fuels that allowed surface fires to spread (Agee 1994). Thus, grazing, fire suppression, and selective logging allowed for the development of the multistoried, overstocked, mixed conifer stands now dominated by true firs and Douglas-firs in the Blue Mountains and elsewhere. These stands are moving towards climax succession as true firs and Douglas-firs encroach upon the previously pine-dominated stands occuping the drier sites in the Blue Mountains--sites that were historically maintained in pine dominance by frequent, low-intensity surface fires. Under the right

conditions, defoliators rapidly increase in these kind of stands. Unchecked rapidly increasing insect populations develop into major, resource-damaging epidemics. During the last decade, defoliator populations in the Blue Mountains have exceeded their historic range of variability because fire exclusion and selective harvesting of pine and larch since the turn of the century have created vast expanses of vegetation conditions that are highly favored as habitat for these defoliators. These management practices have moved plant succession from seral stages to climax condition as shade-tolerant multistoried fir stands have gradually gained dominance on dry pine sites. In essence, because these shade-tolerant climax stands have exceeded their historic range of variability on the drier plant associations, the defoliators have also increased to levels in recent years that are now believed to be outside their historic range of variability.

We have reached the end of the region's latest budworm and tussock moth outbreaks, and they have exacted enormous tolls on our ability to manage and meet many current resource needs in the Blue Mountains. This has affected our ability to meet desired conditions for several of these resources. National Forests' Land and Resource Management Planning efforts did not anticipate outbreaks of this magnitude or severity developing within the planning time-frame. In the case of budworm, this was without a doubt the worst defoliator epidemic in the recorded history of the Blue Mountains. No previous outbreak of budworm that we know of has equalled this in terms of magnitude, intensity of damage, and duration. Much of the current focus on forest and ecosystem health, especially in the Blue Mountains, occurred as a result of the attention garnered by the vast expanses of dead, dying, and defoliated trees left in the wake of the budworm and tussock moth epidemics. However, even the dramatic panoramas of red desiccating current-year foliage clipped-off and webbed into the branch-tip feeding sites by budworm each summer for the past 13 years; the gradual "graying" of the boles of trees as cumulative annual losses of foliage by budworm feeding slowly denuded and killed the tops of crowns; and the more rapid killing of understory trees by defoliation from concentrations of budworm larvae, will soon be all but forgotten. As trees green up again and mask the missing foliage on branches, many people will quickly forget the damage wrought by the budworm, just as many soon forgot the damage caused by the tussock moth outbreak following its collapse in 1974.

As we embark on a grand experiment with ecosystem management, and perhaps consider increasing the amount of late successional stages of vegetation to meet certain resource objectives the public perceives as desirable, will resource managers understand the predictable consequences of trying to maintain these conditions on sites where seral species are better adapted and occurred prior to settlement by European immigrants? Will we recognize the fact that long-term management of many ecosystems that are in late-successional stages in the Blue Mountains will likely result in failure because of insects, diseases, and fire? Will our resource specialists and managers, and the public, understand and acknowledge the fact that many of our forests are already far outside their historic range of variability; that they have been accelerated towards climax succession where

previously they were maintained in early seral stage by frequent, low-intensity surface fires; and that ecosystems in this condition cannot be sustained for long? Do they know that continuing attempts to "manage" these situations will bring about yet other major defoliator outbreaks--budworm, tussock moth, or both--sometime in the future, or else stand replacement fires will destroy the resource conditions we seek to conserve and manage? Are we willing to leave this kind of legacy and promise of future catastrophic defoliator epidemics and stand-replacing fire events to future generations?

These questions must be carefully weighed in the balance of future resource management needs, levels, and trade-offs. The answers to these questions must be integrated into the current and future resource planning and decision processes of our ecosystem management approach, or we will be destined to repeat the past, encumbering future resource managers with the same problems we failed to solve.

The future long-term sustainability of forest ecosystems depends on the choices we make today. Our hope is that whatever those choices are, that they will be made with the full knowledge of the biological implications and probable consequences of forcing ecosystem components to exist beyond the range of variability within which these systems evolved.

There is an innate resiliency of nature. Nature has various ways of healing itself, but we must understand that the further outside its state of normalcy the ecosystem is forced to occupy--like forcing forest vegetation to exist outside its historic range of variability--the more violent nature reacts in its healing processes. Eruptive, catastrophic defoliator outbreaks and fire events are predictable outcomes of a forest ecosystem that has been pushed too far outside its natural range of variability. These episodic insect outbreaks and stand-replacement fire events are some of the natural feedback mechanisms of the forest ecosystem (see Mason 1993) that operate to reachieve the former conditions and the level of adaptation developed over the millennia of time in which these dynamic processes have operated.

Cautious optimism is how we should approach ecosystem management. Mason (1993) has similarly concluded that implementation of ecosystem management with regard to forest pests, should proceed with caution owing to the impact insect and disease interactions can have in unstable systems. The potential for success with ecosystem management is great, but for some situations, the potential for disaster may be even greater. We can only safely manipulate natural ecosystems to achieve resource outputs within the range of variability the component parts can tolerate. When resource management pushes the components outside the biological operating envelop, such as carrying stands beyond their entomological rotation (Keen 1958), a destabilization of that ecosystem occurs, sometimes with dramatic, catastrophic consequences. We need to consider all the implications of any action we undertake within the context of ecosystem management. We need to be prepared for the worst as well as for the best. And we need to be willing to adapt, and adjust our objectives and expectations when the risk of failure appears greater than the probability of

success.

Acknowledgements

I greatly appreciate the assistance of the Silviculture Staffs from the Long Creek, Prairie City, Burns, Heppner, Pomeroy, Walla Walla, La Grande, Unity, and Wallowa Valley Ranger Districts, and the Forestry Staff of the Oregon Department of Forestry, Pendleton Office. Their coordination and scheduling of the insect sampling, and supervising the field crews enabled significant areas of the Blue Mountains to be sampled in a timely manner. I also appreciate the help of Shannon McLaughlin and Peggy Sayer for assisting with the training of field crews, organizing sampling supplies and equipping the crews, coordinating the return of data, and for many hours of entering, editing, and analyzing the sampling data. Special thanks are due Dr. Richard R. Mason, Forestry and Range Sciences Laboratory, La Grande, for helpful comments and advice on an earlier draft, and for many hours of consultation and enlightening discussions on budworm and tussock moth, and for sharing his unpublished defoliator sampling results from the Blue Mountains with me. Dick also assisted in the assessment of the tussock moth outbreak on the Burns Ranger District. Finally, I want to thank Gene Paul, Forestry and Range Sciences Laboratory, La Grande, for rearing field collected tussock moth larvae and egg masses, and for summarizing data on parasitoids and virus prevalence rates from the tussock moth collections.

Literature Cited

Agee, James K. 1994.

Fire and weather disturbances in terrestrial ecosystems of the eastern Cascades. Gen Tech. Rep. PNW-GTR-320. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 52 p.

Christiansen, Erik; Waring, Richard H.; Berryman, Alan A. 1987.

Resistance of conifers to bark beetle attack: Searching for general relationships. Forest Ecology and Management 22: 89-106.

Clendenen, G. 1975.

Tussock moth, *Orgyia pseudotsugata* (McD.), outbreaks and climatic factors: A correlation analysis. USDA Forest Service Cooperative Aid Agreement Preliminary Report. Seattle, WA: College of Forest Resources, University of Washington. 60 p.

Everett, R.; Hessburg, P.; Lehmkuhl, J.; Jensen, M.; Bourgeron, P. 1994.

old forests in dynamic landscapes: Dry-site forests of eastern Oregon and Washington. J. Forestry 92(1): 22-25.

Gast, William R., Jr.; Scott, Donald W.; Schmitt, Craig; Clemens, David; Howes, Steven; Johnson, Charles G., Jr.; Mason, Robert; Mohr, Francis; Clapp, Robert A., Jr. 1991.

Blue Mountains forest health report: New perspectives in forest health. April 1991. Portland, OR: U. S. Department of Agriculture, Forest Service, Malheur, Umatilla, and Wallowa-Whitman National Forests. [Unconventional pagination].

Hazard, John W.; Stewart, Larry E. 1974.

Planning and processing multistage samples with a computer program--MUST. Gen. Tech Rep. PNW-11. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

Hessburg, Paul F.; Mitchell, Russel G.; Filip, Gregory M. 1994.

Historical and current roles of insects and pathogens in eastern Oregon and Washington forested landscapes. Gen. Tech. Rep. PNW-GTR-327. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 72 p.

Keen, F. P. 1958.

Progress in bark beetle control through silviculture in the United States. pp. 171-180 In Proceedings of the 10'th International Congress of Entomology, Vol. 4,

1956, Montreal, Canada.

Mason, Richard R. 1977a.
Advances in understanding population dynamics of the Douglas-fir tussock moth. Bull. Entomol. Soc. Am. 23(3): 168-171.

Mason, Richard R. 1977b.
Sampling low density populations of the Douglas-fir tussock moth by frequency of occurrence in the lower tree crown. Res. Pap. PNW-216. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Mason, Richard R. 1987.
Frequency sampling to predict densities in sparse populations of the Douglas-fir tussock moth. Forest Sci. 33(1): 145-156.

Mason, Richard R. 1993.
The role of pest interactions in forest health and productivity. pp. 95-100 In Proceeedings of the Society of American Foresters National Convention. November 7-10, 1993, Indianapolis, Indiana.

Mason, R. R.; Paul, H. G. 1994.
Monitoring larval populations of the Douglas-fir tussock moth and the western spruce budworm on permanent plots: Sampling methods and statistical properties of data. Gen. Tech. Rep. PNW-GTR-333. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. (in press)

Mason, R. R.; Wickman, B. E.; Paul, H. G. 1989.
Sampling western spruce budworm by counting larvae on lower crown branches. Res. Note PNW-RN-486. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 8 p.

Raske, A. G. 1985.
Collapsing budworm populations. pages 141-142, In: Sanders, C. J.; Stark, R. W.; Mullins, E. J.; Murphy, J., eds. Recent advances in spruce budworms research: Proceedings of the CANUSA Spruce Budworms Research Symposium; 1984 September 16-20; Bangor, Maine, Canadian Forestry Service; U. S. Department of Agriculture, Forest Service; Ottawa, Ontario.

Royama, T. 1984.
Population dynamics of the spruce budworm *Choristoneura Fumiferana*. Ecol. Monogr. 54(4): 429-462.

Scott, Donald W. 1991a.
Biological evaluation of western spruce budworm on 1992 analysis units on the Umatilla and Wallowa-Whitman National Forests. Rep.BMZ-91-04. La Grande, OR: U. S. Department of Agriculture, Forest Service, Wallowa-Whitman National Forest. 54 p.

Scott, Donald W. 1991b.
Lower crown beating procedures for sampling Douglas-fir tussock moth and western spruce budworm larvae. Rep. BMZ-91-02. La Grande, OR: U. S. Department of Agriculture, Forest Service, Wallowa-Whitman National Forest. 6 p.

Scott, Donald W. 1991c.
Sampling Douglas-fir tussock moth and western spruce budworm populations by lower crown beating. Rep. BMZ-91-01. La Grande, OR: U. S. Department of Agriculture, Forest Service, Wallowa-Whitman National Forest. 6 p.

Scott, Donald W.; Schmitt, Craig L. 1994.
Insect and disease conditions on National Forest lands in the Blue Mountains 1990-1993. Rep. BMZ-94-11. La Grande, OR: U. S. Department of Agriculture, Forest Service, Wallowa-Whitman National Forest. 33 p.

Sheehan, Katherine A; Willhite, Elizabeth A.; Eglitis, Andris; Flanagan, Paul T.; Gregg, Tommy F.; Hostetler, Bruce B. 1993.
Regional guidelines for sampling Douglas-fir tussock moth and western spruce budworm. Rep. R6-93-03. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region, Forest Pest Management. 18 p.

Shepherd, Roy F.; Bennett, Dayle D.; Dale, John W.; Tunnock, Scott; Dolph, Robert E.; Thier, Ralph W. 1988.
Evidence of synchronized cycles in outbreak patterns of Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough) (Lepidoptera: Lymantriidae). Mem. Entomol. Soc. Canada. 146: 107-121.

Stelzer, M. J. 1979.
How to determine the occurrence of virus in egg masses. Agriculture Handbk. No. 548. Washington, DC: U. S. Department of Agriculture, Combined Forest Pest Research and Development Program. 7 p.

Torgersen, T. R.; Scott, D. W.; Gillespie, A. J. R.; Hosman, K. P. 1994.
Relationship between lower-crown sampling and midcrown sampling for *Choristoneura occidentalis* Freeman (Lepidoptera: Tortricidae) after treatment with *Bacillus thuringiensis* Berliner. J. Econ. Entomol. 87(x): xxx-xxx (in press).

Willhite, Elizabeth A. 1994.
1993 Douglas-fir tussock moth pheromone trapping summary for Oregon and Washington. Rep. R6-94-03. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region, Forest Pest Management. 9 p.

Table 1. Primary insects and years sampled by lower crown beating on analysis units sampled during 1993 on the Malheur, Umatilla, and Wallowa-Whitman National Forests.

National Forest	Ranger District	Analysis Unit	Primary Insects Sampled by Year[1] 1988	1989	1990	1991	1992	1993	Years[2]
MAL	Long Creek	Cougar Rock					WSBW	WSBW	
MAL	Long Creek	Indian Rock					WSBW	WSBW	
MAL	Long Creek	Sunrise Rock					WSBW	WSBW	
MAL	Long Creek	Pogue					WSBW	WSBW	
MAL	Prairie City	Crane #2						SBW/TM	
MAL	Prairie City	McCoy						SBW/TM	
MAL	Prairie City	North Fork						SBW/TM	
MAL	Burns	Gold Hill					DFTM	DFTM	
MAL	Burns	Rattlesnake					DFTM	DFTM	
MAL	Burns	Thompson Spr.					DFTM	DFTM	
UMA	Heppner	Black					WSBW	WSBW	
UMA	Heppner	Long					WSBW	WSBW	
UMA	Heppner	Skookum					WSBW	WSBW	
UMA	Pomeroy	Skyline						WSBW	
UMA	Walla Walla	Looking Glass					WSBW	WSBW	
UMA	Walla Walla	Lower GR					WSBW	WSBW	
UMA	Walla Walla	Umatilla River					WSBW	WSBW	
UMA	Walla Walla	Upper GR					WSBW	WSBW	
UMA	Walla Walla	Walla Walla Rv.					WSBW	WSBW	
	Umatilla IR.Pvt.	M4D	WSBW	WSBW	WSBW	WSBW	WSBW	WSBW	1988
UMA	Walla Walla/Pvt.	M9D	WSBW	WSBW	WSBW	WSBW	WSBW	WSBW	1988
UMA	Walla Walla	M10D	WSBW	WSBW	WSBW	WSBW	WSBW	WSBW	1988
UMA	Walla Walla	M5T	WSBW	WSBW	WSBW	WSBW	WSBW	WSBW	1988
UMA	Walla Walla/Pvt.	M8T	WSBW	WSBW	WSBW	WSBW	WSBW	WSBW	1988
WAW	La Grande	M12T	WSBW	WSBW	WSBW	WSBW	WSBW	WSBW	1988
	Private	M6C	WSBW	WSBW	WSBW	WSBW	WSBW	WSBW	1988
UMA	Walla Walla	M7C	WSBW	WSBW	WSBW	WSBW	WSBW	WSBW	1988
UMA/WAW	Walla Walla/LAG	M13C	WSBW	WSBW	WSBW	WSBW	WSBW	WSBW	1988
WAW	La Grande	Catherine Creek			DFTM	SBW/TM	SBW/TM	SBW/TM	1991
WAW	La Grande	Indian Creek				WSBW	WSBW	WSBW	1992
WAW	La Grande	LG Watershed					WSBW	WSBW	
WAW/UMA	LG/Walla Walla	Mt. Emily				WSBW	WSBW	WSBW	1992
WAW	La Grande	So. Union			DFTM	SBW/TM	SBW/TM	WSBW	1991[3]
WAW	Unity	Greenhorn					WSBW	WSBW	
WAW	Wallowa Valley	Kuhn-Chesnimnus				WSBW	WSBW	WSBW	1992
WAW	Wallowa Valley	Morgan				WSBW	WSBW	WSBW	1992

[1]WSBW = Western Spruce Budworm; SBW = Western Spruce Budworm; DFTM = Douglas-fir Tussock Moth; TM = Douglas-fir Tussock Moth.

[2]Treated with *Bacillus thuringiensis* (*B.t.*).

[3]Only a portion of the South Union analysis unit was treated during 1991.

Table 2. Total acres sampled for western spruce budworm and Douglas-fir tussock moth in 1993.

Forest	Ranger District	Analysis Unit	Total Acres	No. of Plots	Insect Species
MAL	Long Creek	Cougar Rock	32,000	40	WSBW
MAL	Long Creek	Indian Rock	21,760	40	WSBW
MAL	Long Creek	Sunrise Butte	26,880	40	WSBW
MAL	Long Creek	Pogue	12,800	40	WSBW
MAL	Prairie City	Crane #2	8,960	30	DFTM
MAL	Prairie City	McCoy	4,480	30	SBW/TM
MAL	Prairie City	North Fork	3,200	30	DFTM
MAL	Burns	Gold	34,560	51	DFTM
MAL	Burns	Rattlesnake	37,120	32	DFTM
MAL	Burns	Thompson	40,960	24	DFTM
UMA	Heppner	Black	9,717	30	WSBW
UMA	Heppner	Long	3,021	30	WSBW
UMA	Heppner	Skookum	5,553	30	WSBW
UMA	Pomeroy	Skyline	7,000	30	WSBW
UMA	Walla Walla	Looking Glass	47,150	30	WSBW
UMA	Walla Walla	Lower Grande Ronde	59,760	30	WSBW
UMA	Walla Walla	Umatilla River	149,345	54	WSBW
UMA	Walla Walla	Upper Grande Ronde	36,805	30	WSBW
UMA	Walla Walla	Walla Walla River	88,342	35	WSBW
UMA	Walla Walla	M4D[1]	6,165	5	WSBW
UMA	Walla Walla	M9D[1]	7,617	5	WSBW
UMA	Walla Walla	M10D[1]	6,486	5	WSBW
UMA	Walla Walla	M5T[1]	5,880	5	WSBW
UMA	Walla Walla	M8T[1]	5,367	5	WSBW
UMA	Walla Walla	M12T[1]	7,050	5	WSBW
UMA	Walla Walla	M6C[1]	6,540	5	WSBW
UMA	Walla Walla	M7C[1]	9,330	5	WSBW
UMA	Walla Walla	M13C[1]	11,131	5	WSBW
WAW	La Grande	Catherine Creek[2]	50,000	20	WSBW
WAW	La Grande	Indian Creek[3]	28,885	20	WSBW
WAW/UMA	Walla Walla/La Grande	Mt. Emily[3]	32,227	20	WSBW
WAW	La Grande	La Grande Watershed	7,000	20	WSBW
WAW	La Grande	So. Union[4]	51,000	20	WSBW
WAW	Unity	Greenhorn	30,100	20	SBW/TM
WAW	Wallowa Valley	Kuhn-Chesnimnus[3]	63,300	37	WSBW
WAW	Wallowa Valley	Morgan[3]	36,400	39	WSBW
	TOTALS		629,413	812	

[1]These areas are part of the 1988 Meacham Pilot Project.
[2]Catherine Creek was treated in 1991 for Douglas-fir tussock moth.
[3]Morgan, Kuhn-Chesnimnus, Mt. Emily, and Indian Creek were treated for western spruce budworm in 1992.
[4]Only a portion of So. Union was treated in 1991.

Table 3. Western spruce budworm larval sampling results from the Blue Mountains, 1993.

Forest	Ranger District	Analysis Unit (AU) Monitoring Area (MA)	Sample Size Plots	Sample Size Trees	Budworm Population Density (Mean Larvae + SE)[1] Lower Crown Density Per 3-Branch Sample	Budworm Population Density (Mean Larvae + SE)[1] Midcrown Density Per 18-inch Branch Tip[2,3]	Defoliation of Current-Year[4] Foliated Branch tips (Percent)
MAL	Long Creek	Indian Rock	40	5	0.790 ± 0.163	n.a.	33.2
MAL	Long Creek	Pogue	40	5	0.060 ± 0.021	n.a.	11.5
MAL	Long Creek	Sunrise Butte	40	5	1.115 ± 0.220	0.144	38.2
MAL	Long Creek	Cougar Rock	37	5	0.800 ± 0.233	n.a.	33.4
MAL	Prairie City	McCoy	30	5	0.620 ± 0.110	n.a.	30.0
UMA	Heppner	Black	30	10	1.043 ± 0.261	1.068	37.2
UMA	Heppner	Long	30	10	2.346 ± 0.396	1.426	51.8
UMA	Heppner	Skookum	30	10	1.410 ± 0.275	0.452	42.1
UMA	Pomeroy	Skyline	30	5	0.220 ± 0.054	n.a.	19.6
UMA	Walla Walla	Looking Glass	30	5	0.940 ± 0.323	n.a.	35.6
UMA	Walla Walla	Lower Grande Ronde	30	5	1.786 ± 0.334	0.843	46.4
UMA	Walla Walla	Umatilla River	54	5	0.063 ± 0.0004	n.a.	11.8
UMA	Walla Walla	Upper Grande Ronde	30	5	0.060 ± 0.033	n.a.	11.5
UMA	Walla Walla	Walla Walla River	36	5	1.272 ± 0.272	0.308	40.3
WAW	La Grande	Catherine Creek	20	5	0.00	n.a.	0.0
WAW	La Grande	Indian Creek	20	5	0.00	n.a.	0.0
WAW	La Grande	Mt. Emily	13	5	0.00	n.a.	0.0
WAW	Unity	Greenhorn	20	5	0.060 ± 0.021	n.a.	11.5
WAW	Wallowa Valley	Morgan	37	5	0.010 ± 0.007	n.a.	5.5
WAW	Wallowa Valley	Kuhn-Chesnimnus	39	5	0.035 ± 0.016	n.a.	9.2
ODF	Pendleton	Tollgate	10	5	1.960 ± 0.718	1.024	48.2
ODF	Pendleton	Thimbleberry	8	5	0.945 ± 0.545	n.a.	35.7
ODF	Pendleton	Walla Walla/Mill	10	5	5.060 ± 2.599	4.253	71.0

[1]Conversion of LCB means to midcrown densities based upon regression equation: Midcrown Density = -1.0168 + 1.0414 (LCB); (Torgersen et al., 1994). Standard errors could not be reported for converted means.

[2]Mean population densities for Walla Walla do not include data collected by Oregon Department of Forestry, Pendleton. These data are reported under the ODF heading at the end of the table.

[3]n.z. = not available. The conversion model used to relate lower-crown samples to midcrown densities is valid only for the lower crown density range of 0.98-22.00 larvae per 3-branch sample (Torgersen et al., 1994). Densities indicated by the n.a. notation fell outside the valid density range.

[4]Percent defoliation of current-year foliated tips based on regression equation: Percent Defoliation = 36.557 * $X^{(0.40984)}$; where X = Lower-crown Density per 3-branch sample (Scott et al., unpublished data).

Table 4. Douglas-fir tussock moth larval sampling results from the Blue Mountains, 1993.

Forest	Ranger District	Analysis Unit (AU)	Sample Size Plots	Sample Size Trees	Tussock Moth Population Density (Mean Larvae + SE)[1] Lower Crown Density Per 3-Branch Sample	Midcrown Density Per 1000 sq. in. Foliage	Population Status[2]
MAL	Burns	Gold	51	5	15.941 ± 4.176	63.764	Outbreak
MAL	Burns	Rattlesnake	32	5	33.981 ± 9.293	135.924	Outbreak
MAL	Burns	Thompson	24	5	12.258 ± 3.385	49.032	Outbreak
MAL	Prairie City	Crane #2	30	5	0.073 ± 0.262	0.292	Low
MAL	Prairie City	North Fork	30	5	0.346 ± 0.062	1.386	Low
MAL	Prairie City	McCoy	30	5	0.006 ± 0.006	0.026	Very Low
MAL	Long Creek	Cougar Rock	37	5	0.0	0.0	Undetected
MAL	Long Creek	Indian Rock	40	5	0.005 ± 0.005	0.02	Very Low
MAL	Long Creek	Pogue	40	5	0.0	0.0	Undetected
MAL	Long Creek	Sunrise Rock	40	5	0.010 ± 0.007	0.04	Very Low

[1]Conversion of LCB means to midcrown densities based upon procedure by Mason (1987). Standard errors could not be reported for converted means.

[2]Very Low population = Douglas-fir tussock moth densities ranging from 0.0 to 0.1 insects/1000 sq. in. of foliage. Low populations = Douglas-fir tussock moth densities ranging from 0.1 to 2.0 insects/1000 sq. in. of foliage. Suboutbreak populations = Douglas-fir tussock moth densities ranging from 2.1 to 20.0 insects/1000 sq. in. of foliage. Outbreak population = Douglas-fir tussock moth >20.0 insects/1000 sq. in. of foliage.